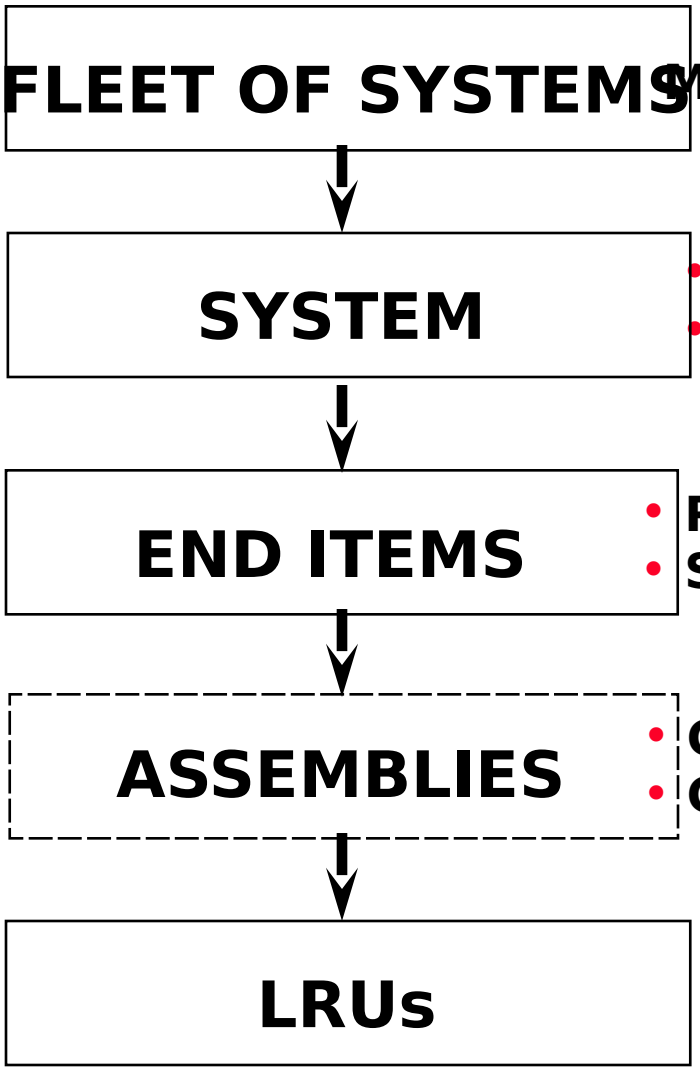
INTEGRATING RELIABILITY, AVAILABILITY, MAINTAINABILITY (RAM) AND SUPPORTABILITY IN REQUIREMENTS

ACHIEVING A SYSTEM OPERATIONAL AVAILABILITY REQUIREMENT (ASOAR) MODEL

Bernard Price

Certified Professional Logistician

ASOAR Equipment Levels of Indenture



- Multiple Similar Systems Used in Mission
- Total Weapon System
- System with its GFE
- Primary Items Being Developed/Acquired
- System Without GFE or GFE Items
- Grouping of Line Replaceable Units
- Common Items in Different End Items
- Secondary Items Replaced Forward
- Items Impacting Maintainability

ASOAR Version 6

- **Allocates Optimum Ao to End Items Being Acquired from System Readiness Rate**
- **Determines Ao Inputs to Use in Supportability Optimization Models**
- **Integrated Analysis of RAM and Supportability**
  - **Used Early-On to Help Generate Requirements**
  - **Determines the Fleet Ao and Mission Reliability When Using Multiple Similar Systems in a Mission**

ASOAR System Level Inputs

- **System Ao/Readiness Requirement**
- **System Operating Tempo per Year, Mission Duration & Percent of System Failures Not Mission Critical**
- **Reliability Configuration Block Diagram of Mission Critical End Items**
  - **Quantity of Each End Item in System**
  - **Serial Configuration End Items**
  - **Redundant Configuration End Items**
    - **Hot or Cold Standby Redundancy**
    - **Full or Degradational Redundancy**

ASOAR End Item Inputs

- **RELIABILITY (Choose One)**
  - **MTBF, Operating Hours/Year & Mission Use Hours**
  - **MMBF, Miles/Year, Average Miles/Hour, Mission Miles**
  - **MRBF, Rounds/Year, Average Rounds /Hour, Mission Rounds**
  - **MTBF, Op Hours/Year, Non Op Hour Failure Rate & Mission Use Hours**
  - **Failures per Year or Mean Calendar Time Between Failure (MCTBF)**

- **MAINTAINABILITY (Choose One)**
  - **Mean Time to Repair (MTTR)**
  - **MTTR & Restoral Delay Time with Spares Forward**
  - **Mean Time to Restore (MTR)**

- **COST (Choose One)**
  - **Cost of Each End Item & Cost of Expensive, Very Low Failure Rate Items**
  - **Relative Cost of End Items to Each Other (May Use Ratios)**

ASOAR Logistics Inputs

- **Forward Support Level Mean Time to Obtain LRUs**

  - or- Determine With Following Inputs:

- **Supply Support Levels Applicable**
- **Maintenance Support Levels Applicable**
- **Repair Percentage at Each Repair Level**
- **Average Order and Ship Times to Lower Support Levels**
- **Stock Availabilities at Higher Support Levels**
- **Average Repair Cycle Time at Each Repair Level**
- **Average Back Order Duration Time at Depot Level**

No Special Cases

DEFAULT SCENARIO:

- **There is One Each of All End Items**
- **Each End Item is Serially Configured in the System**
- **Systems are Restored with LRUs Potentially Spared at the ORG Level**

Sparing Optimization Heuristic

- Cost to Failure Rate to Down Time Ratios Without LRU Spares are Compared (COST X MCTBF / MLRT)
- End Items with the Lowest Ratios Will be Spared First
- More LRU Sparing Lowers MLRT to Increase Ratio
- The LRU Sparing Increase Stops When the Product of End Item Availabilities Equal the System Ao Target
- End Items with a Ratio Higher Than the Final Ratio Meeting the Ao Target Will Have No LRU Sparing

Special Cases Cause Adjustments

- **Scheduled Maintenance or Periodic Startup/Servicing Causing System Downtime Causes Ao Adjustments**

- **Cold Standby Redundancies or End Item Spares with System Causes Reliability & Ao Adjustments**

- **Systems Restored with End Item LRUs Stocked Forward at DS Level Causes Restoral Time Adjustments**

- **Systems Restored with End Item Floats at DS Level Causes Reliability & Restoral Time Adjustments**

GROUP 1 Special Cases

CAUSES Ao TARGET ADJUSTMENT:

CASE 1.1: SYSTEM SCHEDULED MAINTENANCE OR PERIODIC STARTUP CAUSING SYSTEM DOWNTIME

CASE 1.2: END ITEM SCHEDULED MAINTENANCE OR PERIODIC STARTUP CAUSING SYSTEM DOWNTIME

CASE 1.3: COLD STANDBY REDUNDANCY OR END ITEM SPARES WITH SYSTEM (also causes reliability adjustment)

CASE 1.4: COLD STANDBY DEGRADATIONAL REDUNDANCY (also causes reliability adjustment)

ASOAR Conditional Inputs

- **PERIODIC/SCHEDULED SYSTEM DOWN TIMES**
  - **Mean Calendar Time Between Similar Actions**
  - **Average Down Time Duration & Maintenance Hours for the Action**
  - **Repeat Inputs for Each Dissimilar Action**

- **REDUNDANCY**
  - **Number of End Items in System**
  - **Number of Operating End Items (If Cold Redundancy)**
  - **Number of End Items Needed to be Mission Capable**

- **DEGRADATIONAL REDUNDANCY**
  - **Minimum Number of End Items Needed to be Fully Up**
  - **Maximum Number of End Items Needed to be Fully Down**
  - **Percentage of Capability Associated with Each Partially Mission Capable State**

GROUP 2 Special Cases

FORWARD LRU STOCKAGE IS NOT AT ORG LEVEL:

CASE 2.1: SYSTEM RESTORED WITH END ITEM LRUs STOCKED FORWARD AT DS LEVEL

CASE 2.2: SYSTEM RESTORED WITH END ITEM FLOATS AND LRUs STOCKED FORWARD AT DS LEVEL

CASE 2.3: SYSTEM RESTORED WITH END ITEM FLOATS AT DS AND LRUs STOCKED FORWARD AT GS LEVEL

CASE 2.4: SYSTEM RESTORED WITH END ITEM FLOATS AT DS AND LRUs STOCKED FORWARD AT

ASOAR Conditional Inputs

- **Restoral Delay Time When LRU Forward Support Level is Not at ORG Level**
- **Order & Ship Time of Floats from DS to ORG When End Item Floats are Used to Restore System**

GROUP 3 Special Cases

CAUSES RELIABILITY ADJUSTMENTS:

CASE 3.1: SERIALLY CONFIGURED COMMON END ITEMS

CASE 3.2: HOT STANDBY REDUNDANT END ITEMS

CASE 3.3: HOT STANDBY DEGRADATIONAL REDUNDANCY OR CAPACITY AVAILABILITY

CASE 3.4: HOT STANDBY REDUNDANT END ITEMS AND SYSTEM RESTORED WITH END ITEM FLOATS

CASE 3.5: HOT STANDBY DEG REDUNDANCY AND SYSTEM RESTORED WITH END ITEM FLOATS

GROUP 4 Special Cases

MISSION USES MULTIPLE SIMILAR SYSTEMS:

CASE 4.1: ALL SYSTEMS NEEDED TO BE FULLY MISSION CAPABILITY – NO PARTIAL CAPABILITY STATES EXIST

CASE 4.2: NOT ALL SYSTEMS NEEDED TO BE FULLY MISSION CAPABILITY – NO PARTIAL CAPABILITY STATES

CASE 4.3: PARTIAL MISSION CAPABILITY APPLIES & ALL SYSTEMS ARE NEEDED TO BE FULLY MISSION CAPABLE

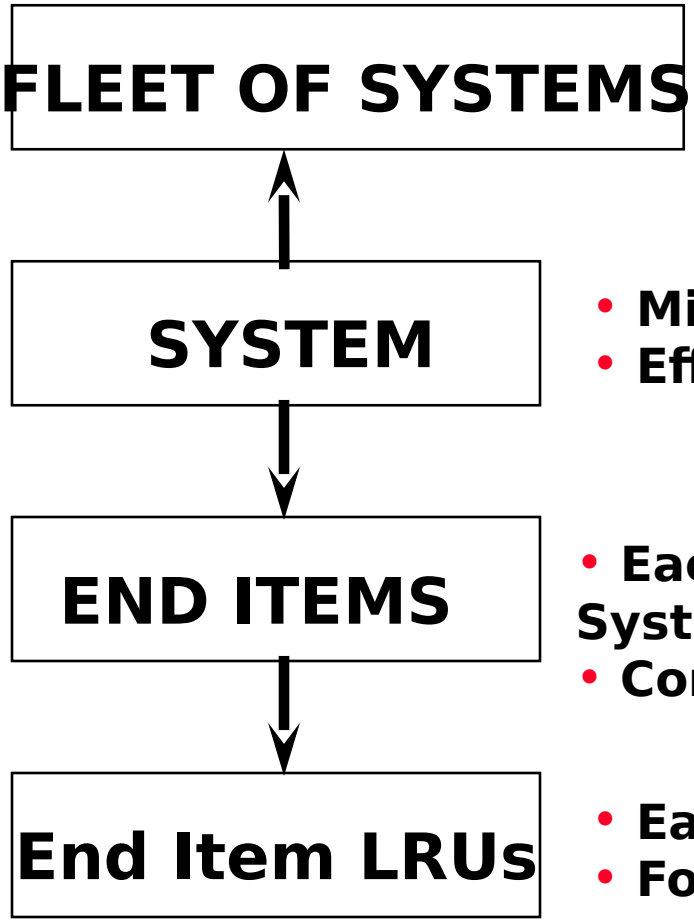
CASE 4.4: PARTIAL MISSION CAPABILITY APPLIES

When Mission Use Requires Multiple Similar Systems

- **Mission Capability Inputs**
  - **Total Number of Systems in Fleet to Draw From for Mission**
  - **Total Number of Systems to be Used for Mission**
  - **Minimum Number of Systems Up to be Fully Capable**
  - **Maximum Number of Systems Up to be Non-Capable**
  - **Degree of Upness When Partially Capable**

- **Outputs for Mission Use of Multiple Systems**
  - **Probabilities for Number of Systems Available**
  - **Mission Reliabilities for Number of Systems Available**
  - **Fleet Mission Success Probability of Being Available for Mission and Lasting the Mission Duration**

Key ASOAR RAM & Log. Outputs



- Ao, Reliability & Capability Probability States
- Probability Of Fleet Mission Success

- Mission Reliability & Maintenance Ratios
- Effective System Reliability & Maintainability

- Each Ao & ALDT Optimally Allocated from System Ao
- Common EI Configuration Ao & Reliability

- Each LRU Order Fill Rate Based on Allocation
- Forward Level Mean Time to Obtain LRUs

ASOAR Computational Notes

- **Reliability, Availability & Supportability Analyses**
  - **Effective Reliabilities, Ao, ALDT & LRU Fill Rates are Based on Calendar Time Failure Rates (Internally Uses MCTBF)**
  - **Mission Reliability is Based on Operating Failure Rates to Determine Probability of Lasting System Mission Duration**

- **System Maintenance Ratio Built Up in terms of Labor Hours per System Operating Hour**
  - **MReff Uses MTTR & Computed System MTBF for Failures Causing System Restoral Corrective Maintenance**
  - **MRp of Periodic or Servicing Actions Uses Action Frequency & Labor Time for Non-Hardware or Non-Corrective Maintenance**
  - **MRneff Uses MTTR, % of Total Failures Non-Critical & Corrective Maintenance on Redundant End Items Not Causing System Failure**

Maintenance Ratio Yields Fleet Maintenance Personnel Requirement

$$MR = MR_p + MR_{eff} + MR_{neff}$$

$$\frac{\text{System Maintenance Man Hours}}{\text{Year}} = MR \times \frac{\text{Operating Hours}}{\text{Year}}$$

$$\frac{\text{No. Maint Personnel}}{\text{Fleet}} = \frac{\text{System Maint Man Hours}}{\text{Year}} \times \frac{\text{No. Systems}}{\text{Fleet}} / \frac{\text{Productive Man Hours}}{\text{Year}}$$

ASOAR Model Usefulness

- **Early-On RAM Requirements Analysis of a System**
  - **Helps to Determine Mission Reliability, Maintenance Ratio & Ao ORD Requirements**
  - **Assesses Whether System Ao is Achievable & Optimally Allocates the System Ao Requirement to its End Items**

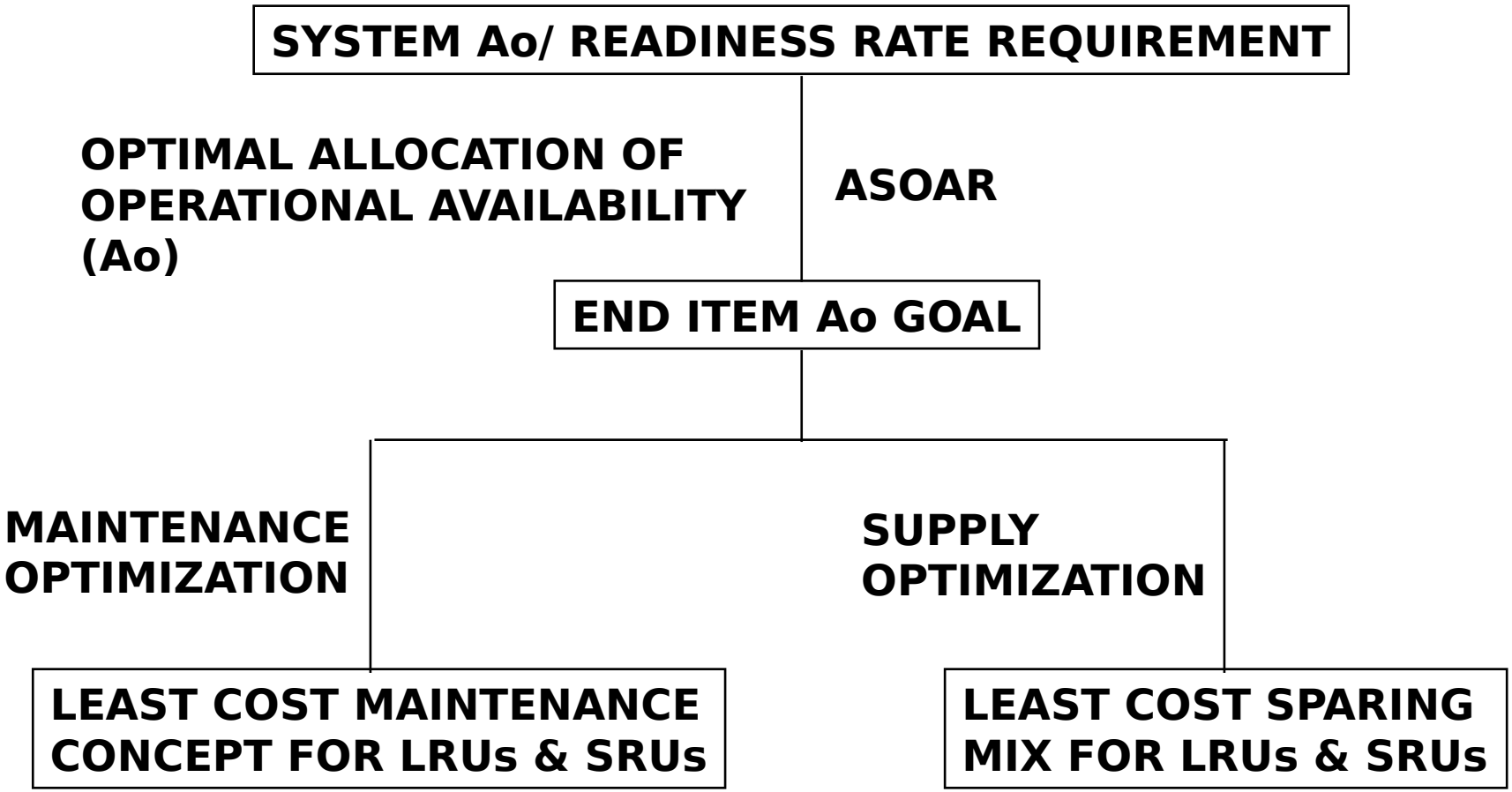
- **Early-On System Reliability & Supportability Analysis**
  - **Assesses Degree of Logistics Support Affordability**
    - **High LRU Order Fill Rate Output is More Expensive**
    - **Low LRU Order Fill Rate Output Reduces Log Footprint**
  - **Permits Sensitivity Analysis of Ao or Support Concepts**
  - **Determines System Reliability & Permits Sensitivity Analysis of System Design Reliability Configuration**

ASOAR Model Usefulness

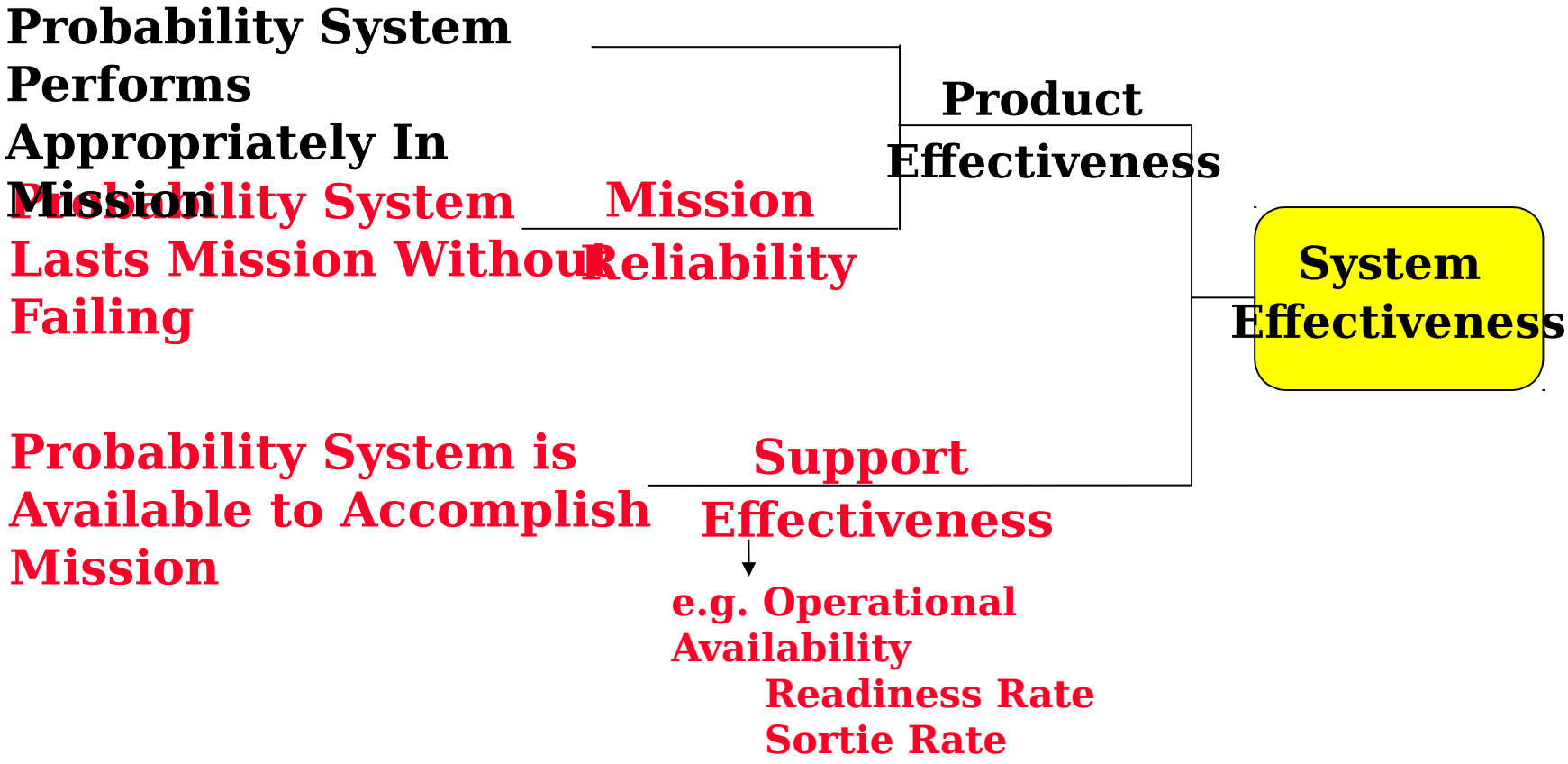
- **Help Requirements Community to Perform RAM Rationale Effectively**
  - **Provides Integrated RAM Computations – No Longer an Off-Line Analysis**
  - **Determines Cost Effective ALDT as Output – Not an Estimated Input**
  - **Makes Availability a Part of R&M Requirements Analysis**

- **Relates RAM Requirements to User Outcomes**
  - **Forward Level Maintenance Personnel Requirements Based on Maintenance Ratio & Operating Tempo**
  - **Determines Mission Success Rate for System or Fleet Based on Availability to do Mission & Mission Reliability**

System Supportability Optimization Modeling to Operational Availability


SYSTEM Ao/ READINESS RATE REQUIREMENT
OPTIMAL ALLOCATION OF OPERATIONAL AVAILABILITY (Ao)
ASOAR
END ITEM Ao GOAL
MAINTENANCE OPTIMIZATION
SUPPLY OPTIMIZATION
LEAST COST MAINTENANCE CONCEPT FOR LRUs & SRUs
LEAST COST SPARING MIX FOR LRUs & SRUs

System Effectiveness



System of Systems Modeling

- **Tailored System of Systems Mission Reliability & Availability Analysis Spreadsheets Used**
- **Perform Separate ASOAR Analysis of Each Different System to Determine Their (Fleet) Mission Success Rate**
- **System Mission Success Rates for each Different System are Multiplied to Estimate System of System Mission Success Rate**